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SIGATOKA DISEASE OF BANANAS IN HONDURAS AND ITS CONTROL

BY

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ABSTRACT

During the latter part of November and the first of December 1942, a detailed study was made of all experimental and field tests conducted by the Tela Railroad Company from 1936 through 1942 on the Control of Sigatoka Disease of Bananas. The purpose of these studies was to determine whether or not copper fungicides were necessary for control and, if so, whether or not the accepted copper spray was used efficiently. A careful study of all investigations showed that no substitute sprays or dusts included in the sulfur, organic, and other miscellaneous fungicide groups were efficient for control. This left the copper lime dust and copper sprays as the most efficient. Copper lime dust proved to be more costly to apply. It required for control slightly more pounds of copper sulfate per acre than Bordeaux mixture and therefore was replaced entirely in favor of Bordeaux mixture. Among the copper fungicides tested, Bordeaux mixture was found to be the best. Of all the various formulas of Bordeaux mixture tested, it was concluded that the 5-5-50 formula was the most efficient for farm control. Extensive experiments and field trials covering a period of years from 1936 through 1942 with this mixture have shown the following:

That the most efficient average number of sprays to apply per year lies between 15.3 and 17.0 with a possible average of between 15.4 and 15.8. The latter figures should serve as a yardstick.

That the most efficient gallonage of spray to apply per acre varies between 260 and 270 gallons.

Utilizing the above figures on number of sprays per year and gallons per acre per spray, it was concluded that between 408 and 419 pounds of copper sulfate per acre per year were required for practical farm control on plantations with newly planted and mature bananas and between 412 and 423 pounds of copper sulfate per acre per year on plantations with mature bananas. It is assumed that these figures may be used as a yardstick for the evaluation of the efficiency of spraying operations conducted under conditions similar to those practiced in Honduras.

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INTRODUCTION

Sigatoka disease was first reported in the Central American Banana countries in August 1935 as occurring in banana plantations located in the Ulua Valley near La Lima, Honduras. Since that time, it has been reported from all Republics in Central America where bananas are grown. Disease spread and severity of infection were so great that the disease finally became the limiting factor in banana production. One year after its appearance in Honduras, a total of 10,000 acres of bananas was classified as out of production from the effects of the disease. Within two years, the disease had eliminated production from all unsprayed bananas in the Ulua and Chamelecon Valleys of Honduras. These cultivations, at that time, covered an area of 50,000 acres. The severity of the disease was such that it was feared the entire banana industry would be ruined. The banana companies immediately initiated control investigations which led to a spray practice that eventually brought the disease under control. Attempts in recent years to reduce the spray programs, or to eliminate spraying entirely, resulted in the reappearance of severe infection and entire loss of commercial fruit. Today all banana acreage must be thoroughly sprayed for banana production. Better cultural practices, necessitated by the spray program, resulted in the production of higher yields. These increased yields made it possible for the fruit companies to conduct a costly spray program and still stay in business.

The United Fruit Company, through its subsidiary the Tela Railroad Company, has conducted the chief research on the problem as it applies to Central America. These studies are being made in Honduras where banana growing conditions are, in the main, representative of the other banana regions of Central America. The investigations were conducted from the time of the first appearance of disease, in 1935, up to date.

During the latter part of November and the first of December 1942, the writer made a thorough study of the investigations for the present report. For these studies the Tela Railroad Company submitted all records and reports dating from 1935 through 1942. Cost figures along with copper sulfate shipments during this period also were made available. This ready access to all data and field experimental plots made it possible to evaluate accurately the control practices and especially the need of copper sulfate in control.

The purpose of this report is to present a picture of the symptoms and behavior of the disease in order to point out the absolute necessity of spraying for control and to determine whether or not the following points were carefully considered in concluding that Bordeaux mixture spray is the only one which will affect control: If adequate cultural field control

practices were tested; if all known fungicides, including dusts and spray mixtures, were given a thorough test; if substitute sprays for copper were thoroughly tested; and if stickers and spreaders were tested in attempts to increase efficiency of sprays. Since Bordeaux mixture was determined to be the only fungicide that could be used, analyses of the following experiments were made to determine whether or not these tests were conclusive enough to prove the following factors: The most efficient concentration of the spray mixture necessary for control; the most efficient spray cycle which will result in the least number of sprays required per year; and the gallonage of spray material necessary per acre. The final result of this investigation is aimed at the determination on a scientific basis of a formula for the computation of the amount of copper sulfate needed per acre for normal farm control of Sigatoka disease of bananas. This formula should, with slight variations because of differing local conditions within the various countries, apply to the control of disease in the Republics of Guatemala, Honduras, Costa Rica, and Panama.

SYMPTOMS AND NATURE OF THE DISEASE

Sigatoka disease is caused by a fungus that attacks the leaf system of the plant producing distinct yellowish or brown spots. In severe cases of infection, spots may be so numerous that they merge and cause a blotching, (Figs. I and II). A toxic material produced by the fungus in severe infection causes a scorching of the leaf, (Fig. II). Under such conditions, a plantation of bananas looks as if a fire had gone through the same and production of normal fruit ceases. The fungus present within the spots produces spores on the leaf surface. These are blown or washed by dew or rain to healthy leaves and, in this manner, spread infection. Since each spot may produce as many as 600 spores, an enormous number of these from all infected leaves, is produced to cause spread. It takes 35 days for new spores to be produced after each initial infection. New crops of spots and spores therefore may be produced every 35 days. This fact explains the rapid spread and severity of the disease once a plantation becomes infected.

The leaves of severely infected plants are killed, thereby destroying the food manufacturing areas, (Fig. III). Banana leaves manufacture all the food which is used by the plant to form fruit. When the leaf is killed, the food manufacturing areas are destroyed. In severe cases of infection and defoliation, either no fruit or only small partially developed fruit is produced, and commercial production of fruit is entirely stopped, (Fig. III).

Under practically all Central American banana growing conditions, the climate is conducive to severe disease production. The most favorable conditions are a continuous supply of free water either in the form of dew or rain, a temperature of around 80° F. and a humidity that does not fall below 70° F. During the dry season, disease in the banana areas is not as severe as it is in the rainy season. Spore production and disease, however, are

always present during the dry season in sufficient quantities to cause trouble and carry the infection over to the rainy periods. Disease spread, therefore, continues throughout the year, being most severe during the rainy period and less in the dry season. For this reason, spraying for control must be practiced in every month of the year.

The disease producing organism does not live in the soil. It can only attack banana leaves and reproduce itself on these leaves. Because of this, the only control on banana varieties susceptible to disease is to spray the leaves with a fungicide that will kill the fungus spores before they can grow and penetrate the leaves.

Since the disease is spread only by spores of the fungus, the presence of abandoned, diseased areas with their enormous spore production has been found to be a serious hazard for adjoining sprayed areas, (Fig. V.). Before control by spraying could be obtained under these conditions, it was found necessary to cut down and destroy such old plantings. Most efficient control of the disease has been obtained only when the entire banana area is included in the spray program.

EXPERIMENTS ON CONTROL

Sanitation

In the early days of experimentation on control, it was thought that the removal of old infected leaves from the plant and ground, and the destruction of the same might effect a control. Tests run over a period of a year proved this practice to be ineffective. Cutting off of dead or spotted leaves gave little or no control since many of the clean leaves were already infected. Attempts to keep a plant relatively free from infection by removal of diseased leaves resulted in practically defoliating the plant, thereby reducing the food manufacturing leaf surface to a point where normal fruit production was impossible. In other words, the removal of leaves by this means produced the same result as that done by the fungus during severe infection.

Fertilizing

The severity of infection in certain plant diseases seems to be dependent upon soil or fertility. While there was no direct evidence that this might be so in the case of the Sigatoka disease, fertilizer trials were started in 1936 to at least prove the point one way or the other. The generally accepted plant fertilizers were applied, to be certain that a lack of these was not an aid to severe disease production. The so-called minor elements were also used to ascertain whether or not the absence of one or the other of these made the plant susceptible to disease. The following chemicals were applied to the soil in banana experimental plots: muriate of potash, acid phosphate, urea, ammonium sulfate, manganese sulfate, ferrous sulfate, zinc sulfate, copper sulfate, sulfur, hydrated lime, boron, and milorganite. No effect,

beneficial or otherwise, on Sigatoka disease was noted. It is believed that these tests were carefully conducted with all important chemicals and that this possible phase of disease control was eliminated for further consideration.

Resistant Varieties

A variety planting of the better commercial banana varieties in the world is located at La Lima, Honduras. Disease records kept over a period of years have shown that none of the commercial varieties are sufficiently resistant to replace the present Gros Michel banana that is universally planted. Fifty-one different varieties were tested: Among these were the following possible commercial strains: Cavendish strain, Lady Finger, Lacatan, Bungulan, and Giant Fig. In addition to these bananas, the Standard Fruit and Steamship Company, on their Olanchito farms, had tests with the Panama and Sigatoka resistant strains I.C.2 from Trinidad and S.19 from Jamaica. While these hybrids showed resistance to both diseases, the fruit bunch was poor and not suited for commercial purposes. These tests were investigated by the writer on December 5, 1942.

Some of the plantains and seed banana strains in the La Lima collection showed resistance. This was also true of Abaca or Manila Hemp (Musa textilis), which is a species of banana.

Attempts to Grow Bananas Without Fungicidal Control

During the first two years of disease, attempts were made by independent growers to control disease without spraying. One outstanding example was the holding of Mr. Manuel Garcias' at Birichichi. In December of 1936, when the writer went over this holding, there was very little disease present. The farm was located on the Ulua River and was one of the prize banana farms of some 1200 to 1500 acres. Disease appeared during 1936 and attempts to grow bananas, without spraying or dusting, by specially heavy pruning and clearing of diseased leaves and plants resulted in failure. Today the entire farm except some five acres of experimental planting is abandoned.

The Tela Railroad Company had to keep the diseased plants of the abandoned plantation cut down in order to obtain complete control of the sprayed area across the river. The vast number of spores produced in the diseased planting blew over to the sprayed bananas and made it impossible to obtain complete control in spite of the intensive spray measures practiced.

The small planting not cut down had severe infection on Nov. 30, 1942, when the writer inspected the same, and produced only a few abnormal bunches of bananas that were fed to livestock (Fig. III). On the north coast of Honduras, 20,700 acres of bananas had to be abandoned by independent growers because of inability to protect the same from disease by other methods than spraying. There appears to be no question but what control of Sigatoka disease will have to be kept up as long as bananas are produced in Central America.

The success with the spray control program during 1936 and 1937 and the healthy state of the sprayed bananas brought up the question of whether or not the fungus had diminished to such an extent that spraying was no longer necessary. A test to prove whether or not bananas in a locality free from disease due to spraying would remain free without spray was started in March 1938. This test was placed in Section 28 of Guaruma II Farm near La Lima. At this time, the area was one of the cleanest, from a disease standpoint. It remained clean throughout the drier months, but, with the advent of rains, an outbreak of primary infection started during the early part of June. Disease spread rapidly during the succeeding months and it became necessary to resume spraying on September 22, 1938 in order to save the bananas. This test proved that spraying was still absolutely essential if damage from disease is to be avoided. Apparently the disease cannot be eradicated.

Dusts and Sprays

Since carefully conducted tests on control by the use of sanitation, fertilizing, and resistant varieties failed to produce the desired results, control of Sigatoka disease was limited to the use of dusts and sprays. These operations are expensive and frequently can be only economically practiced when the most efficient use of the essential chemicals is employed. The Research Department of the United Fruit Company at its Tela Railroad Company subsidiary in Honduras, ran extensive tests to first determine what fungicides, if any, would control the disease and then to determine the best method of application either by means of dusts or sprays. When these points were settled, the important consideration of reduction in costs was tackled. An analysis of these tests follows:

Dusts

The Company reports show that during the past seven years experimental and field tests have been carried out with all fungicidal dusts which appeared to offer possibilities in Sigatoka control. These fungicides were compared with Bordeaux 5-5-50 and 3-3-50 sprays, both from control and cost standpoints, in evaluating efficiency. The results of these tests are summarized in a table as Supplement I of this report.

The following dusts were given a thorough trial during 1936, 1937, and 1938: Copper lime dust (20-80); Copper lime dust (40-60); Sulfur dust (finely divided), (Stauffer Chemical Co.); Copodust; and Kolodust. Tests in 1936 with dusts showed that copper lime dust was the only one that offered much hope of control. In 1937, Copper lime dust (20-80) applied usually at the rate of approximately 80 lbs. per acre, was used in all field tests. The 20-80 formula of copper lime dust consists of 20% monohydrated copper sulfate and 80% hydrated lime. At the rate of 80 lbs. to the acre, approximately 16 pounds of copper sulfate were applied per application.

The aeroplane dusting program included 1964 acres during December 1936 and 11,326 acres for December 1937 (Fig. XI). The research reports for the year 1937 stated that dusting faced several adverse conditions in the Ulua and Chamelecon Valleys. Chief among these were the short period of time the leaves remained wet enough to dust effectively and the occurrence of fogs during the best dusting hours. Only two to three hours per day could be depended upon. It was also noted that the amount of control was not as satisfactory as spraying. In view of those findings, the acreage for dusting in 1938 was reduced to 5,000 acres for experimental purposes.

A study of the comparative records of spraying and dusting work during 1938 showed that aeroplane dusting was inefficient. In all cases where spray had replaced dust, much better results with monthly applications of 5-5-50 Bordeaux were obtained than with 14 day applications of dust. During the entire two and one half years of operation sufficient control with dust was never achieved by varying cycles or applications, while the cost of spraying with maximum efficiency was reduced by varying cycles and gallonage. Aeroplane dusting finally proved to be more costly as well as inefficient. The dusting program was therefore completely abandoned in October 1938 in favor of spraying.

One experimental dusting plot started on March 17, 1936, on a 14 day cycle has been retained to date. On November 20, 1942, an examination of this plot by the writer showed poor control as compared to that of the 5-5-50 Bordeaux plots. According to the Company's research reports, copper lime dust, which gave fair control for a considerable length of time with small power duster, broke down completely in the experimental plots during the 1940 rainy season. A summary of the dust experiments conducted from 1936 through 1942, is given in the table attached as Supplement I of this report.

From a standpoint of copper sulfate consumption, the dusting operation used approximately 16 pounds per acre per application as against 26.5 lbs. per acre per application for the 5-5-50 Bordeaux mixture. It took, however, 26 dusts during the year on a 14 day cycle to produce a partial control as against 15.6 Bordeaux sprays per year to produce a complete control. At these rates, 416 lbs. of copper sulfate per acre per year were used in the dusting operations as compared with 413 lbs. per acre per year for the Bordeaux spraying operations. The dusting operations cannot, therefore, be considered further in a program that would call for a reduced consumption.

Sprays

A study of the Company experiments on spraying with various spray fungicides from 1936 through 1942 is summarized in Tables I, II, and III, and in a table attached as Supplement I of this report. All important fungicides now on the market were included in these tests.

TABLE I - COPPER AND SULFUR SPRAYS

Tested 1936 to 1942

COPPER GROUP

Effective:

Bordeaux 5-5-50

Partially effective:

Bordeaux 4-4-50
Bordeaux 3-3-50
Yellow Cuprocide 1616B
Standard Peronox
Peronox Bentonite
Microgel

Ineffective:

Bayer Concentrate
Copper oxychloride
Tribasic copper sulfate
Fungicide "26"
Ammoniacal copper carbonate
Copper Zeolite
Bordeaux 2-2-50
Bordeaux 2-2-50 and potassium permanganate
Red Cuprocide "54"
Copper Hydro 50
Funtrogen
Copper solution
Anhydrous copper sulfate
Burgundy Mixture

SULFUR GROUP

Partially effective:

Lime sulfur (in dry season)
Flotation sulfur cream (in dry season)
Sulfur dust (in dry season)

Ineffective:

Blood albumen wettable sulfur
Sulfocide
Fungine
Sulforon
Magnetic wettable sulfur

TABLE II - SPRAYS AND DUSTS

Tested 1936 to 1942

Experimental Plots in Guaruma II and Guaruma III Farms
(Now in Operation)

COPPER GROUP	SULFUR GROUP	ORGANIC GROUP
Basic copper sulfate (1939)*	Lime Sulfur (1936)*	Spergon (1941)*
Bordeaux 5-5-50 (1936)	Magnetic sulfur paste (1942)	Fermate (1942)
Bordeaux 3-3-50 (1937)	Sulfur dust, finely divided (1936)	
Cuprocide 1616B (1942)		
Copper lime dust (1936)		
Peronox bentonite (1940)		
Microgel (1940)		

* Date when started.

An analysis of all experiments with spraying materials follow:

Copper group: According to the data presented in Table I, out of 21 fungicides tested in the copper group, only Bordeaux 5-5-50 was found to be suitable for efficient control on a field basis, (Figs. VI and VII). A group of seven was found to be at least partially effective. Tests over a longer period of time will have to be conducted with these for final results.

A number of these fungicides have been under test since 1936 in experimental plots located on Guaruma II and III farms near La Lima, Honduras, Table II. They include all fungicides that were considered by the Company to have at least some merit. Records taken of the latter on November 20, 1942, by the writer showed that basic copper sulfate and copper lime dust, both applied on a 14 day cycle gave only fair to poor control. All other copper fungicides were applied on a 21 day cycle. Bordeaux mixture 5-5-50 showed best control, with Yellow Cuprocide 1616B, Perenox Bentonite and Microgel following with somewhat less effective control. Bordeaux mixture 3-3-50 showed less control. These data compare closely to that obtained over a period of years in all tests summarized in Table I and Supplement I of this report. While a number of copper fungicides proved almost as effective as Bordeaux 5-5-50, it was found that Yellow Cuprocide 1616B and Perenox Bentonite both caused copper injury to the leaf and fruit. The compound listed as Microgel appeared to be equal to Bordeaux 5-5-50. Further tests are required to prove these preliminary results. Since, however, all of the copper fungicides were used at the same copper content per spray, the amount of copper used for each would be the same. All calculations in regard to copper sulfate requirements, therefore, can be based on a study and evaluation of the amount of Bordeaux mixture 5-5-50 spray required for control.

Sulfur Group: In the sulfur group, two sulfur spray materials and one sulfur dust were found to be partially effective out of the eight different ones tested. In data presented, Supplement No. I, covering tests from 1935 through 1942, it was found that the sulfur fungicides gave only partial control.

During the first tests conducted in 1936 with lime sulfur solution 1-40 and Bordeaux mixture 5-5-50, no advantage of one over the other was noticeable for several months, but with the advent of heavy rains in April and May, severe infection occurred in plots sprayed with lime sulfur while Bordeaux sprayed areas carried through in excellent shape (Figs. VII and VIII). Attempts to bolster lime sulfur with the addition of a wettable sulfur and with spreaders and stickers such as sugar and fish oil soap showed no satisfactory results. The three materials, therefore, that gave partial control were only effective during the dry period of the year and fell down completely during the rainy season. All sulfur fungicides also leave a residue on the fruit which is extremely difficult to remove.

A study, made by the writer on November 20, 1942, of the sulfur fungicides used in the permanent spray plots on the Guaruma Farm (Table II) substantiated the results presented above. Trials with magnetic sulfur paste for the first time were included in these tests. The first application of this material was made on November 2, 1942, so no data is available to date.

For practical farm control, it appears, therefore, that all sulfur sprays or dusts have been eliminated. Their only usefulness might be in a spray program that included a sulfur during the dry season. Because the sulfurs all leave a residue on the fruit, that cannot be removed by any known efficient method, this material could not be utilized even under these conditions if fruit is to be marketed.

Miscellaneous Sprays: Fungicides other than copper and lime, tested during the 1936 to 1942 period are listed in Table III.

TABLE III - FUNGICIDES - MISCELLANEOUS SPRAYS

Tested 1936 to 1942

ORGANIC GROUP	MERCURY GROUP	PHENOL GROUP	DYE STUFF
Spergon (Ineffective)	Semesan (Ineffective)	Dowacide A	Orange Helione
Fermate (New test 1942)		R. T. "50"	(Ineffective)
		(Both ineffective)	

SODIUM SALICYLANILIDE
Shirlan (Ineffective)

All included in the Mercury, Phenol, Dyestuff, and Sodium groups proved to be ineffective. In the organic group, Spergon fell down badly (Figs. IX and X). The product Fermate was applied only once, on November 1942, so no results were evident up to date. These compounds contain no copper and are the only substitutes now on the market other than sulfur which could possibly replace a copper spray. It is hoped that Fermate will show effective control.

Stickers and Spreaders

Frequently the efficiency of fungicidal sprays may be increased by the use of a sticker or spreader. They often increase the sticking quality of a spray material and spread the spray more evenly over the leaf surface. When this is accomplished, the efficiency of the spray may be increased and the amounts needed thereby reduced. The Research Department of the Tela Railroad Company tested the following materials in combination with the most promising spray mixtures:

1. Sugar
2. Molasses
3. Powdered skim milk
4. Fish oil soaps
5. Palustrex
6. Penetrol
7. Aresket-240
8. Grasselli SS-3
9. Sandevit
10. Lethane spreader
11. B-1956 emulsifier with Calol
12. Argral
13. Moytol
14. Daxad dispersing agent
15. Kayso

None of the materials were found to increase the efficiency of any of the copper or sulfur sprays. These materials did not make it possible to lengthen the spray cycle and thereby reduce the cost of material used. Bordeaux mixture possesses excellent sticking qualities and usually spreads well. Its efficiency in the above tests could not be increased. Because of this excellent control without the use of spreaders and stickers, it was concluded that the added cost of the material was not warranted.

Spray Equipment

Experiments conducted from 1936 through 1937 showed conclusively that permanent spray installations were much more efficient than portable spray outfits or overhead irrigation methods of application. The former, therefore, were installed as rapidly as possible.

In 1937, the area under stationary spray installations jumped from 1130 acres at the end of 1936 to 21,888 acres one year later. In 1939, the Tela Railroad Company had 38,623 acres of spray system installed. During the same year, stationary spray installations were extended to cover practically all of the United Fruit Company's producing acreage in Honduras, Guatemala, Costa Rica, and Panama. The total spray installations amounted to 103,000 acres requiring more than 5,200 miles or nearly 28,000,000 feet of pipe. In 1942, the acreage under permanent spray system in Honduras was extended to 40,456 acres. This included 35,834 acres of company lands, and 4,622 acres of independent growers' land. The equipment of the latter was financed and installed by the Fruit Company.

The permanent spray equipment consists of a mixing plant with pump and tanks and the permanent pipe system which is laid at one hundred feet intervals throughout a banana farm. At definite intervals along the pipe system are installed take-off faucets to which spray lines with nozzles may be attached to spray the bananas. The spraying operations and equipment are shown in Figs. XII and XIII.

Fruit Washing and Equipment

During spraying operations, the banana fruit is covered with a spray residue. This is objectionable to the banana trade and must be removed before the fruit can be sold. Tests with various chemical solutions to remove the residue were conducted on fruit sprayed with sulfur and copper fungicides.

No solvent was found that could be used successfully to remove the sulfur residue. This, therefore, remains one of the chief obstacles to a sulfur fungicide. Hydrochloric acid solution, in concentrations of 1.3% to 13% (dry weight) were tried without success. The following other acid solutions were tested and found ineffective: sulfuric, nitric, acetic, and carbolic. Mixtures of hydrochloric acid plus salt, sodium silicate, and carbolic acid also were unsuccessful.

All copper spray residues were easily removed by dipping the fruit in a hydrochloric acid solution at strengths varying from .5% to 1.0%. Bordeaux residue is successfully removed by dipping in the solution for 20 to 60 seconds and then rinsing in water.

All fruit suitable for shipping must first be dipped to remove residue. This operation is done at the various railroad fruit loading stations located throughout each farm (Fig. XIV).

<u>Costs of Spraying and Washing</u>. - The Sigatoka disease control investment for the Tela Railroad Company and independent growers in 1942 amounted to $1,660,318.42. In 1941, the total operating costs of spraying and washing of

fruit was $1,681,952 and for the first 10 months of 1942, a total of $1,688,039. The costs per project acre amounted to from $41.14 to $44.99 for the years 1939 through 1941. A summary of these data submitted by the Tela Railroad Company is attached to this report as Supplement No. II.

This great investment, plus cost of operation made it imperative for the Company to bring their costs of operation down to the lowest possible figure. Because of the high cost of spraying, it is essential that every banana farm operation be as efficient as possible. Without the most efficient control, along with the most efficient methods of cleaning, pruning, and irrigation to increase yield of fruit per acre, it would not be possible to grow bananas at a profit.

BORDEAUX MIXTURE

The experimental tests with the various fungicides as listed in Tables I, II, and III, and in Supplement No. I of this report, clearly show that the copper fungicides are the only ones that give complete control. Of these, Bordeaux mixture leads the group. Even though some of the other copper compounds eventually would prove to be as effective as Bordeaux, they would not change the copper requirements, because all must be used on an equal copper content basis for effective control. As soon as it was determined that Bordeaux mixture was the most effective fungicide tested, experiments were conducted by the Company to determine the most efficient concentration, the least efficient number of sprays per year and finally the least gallonage of Bordeaux per acre for efficient control. In an evaluation of these fungicide tests, the writer took into consideration that practically complete control of disease is essential to be effective for farm control on such a tremendous acreage. Field tests have definitely shown that partial control is not enough to hold the disease. Complete loss of control is most likely to follow when control operations are temporarily suspended or seriously interfered with because of unfavorable weather and consequent inability to apply sprays when most needed. A review of these tests follows.

Experiments to Determine the Most Efficient Concentration

In order for the layman to interpret the Bordeaux formulas mentioned in this section of the report, it might be stated that Bordeaux mixture is made of a combination of copper sulfate, hydrated lime and water. A 5-5-50 Bordeaux mixture consists of 5 pounds of copper sulfate, 5 pounds of hydrated lime and 50 gallons of water. A 2-2-50 formula contains 2 pounds of copper sulfate, 2 pounds of hydrated lime and 50 gallons of water. Therefore, there is 2.5 times as much copper sulfate in a 5-5-50 mixture as there is in a 2-2-50 mixture. If a 2-2-50 Bordeaux would control the disease as well as a 5-5-50 Bordeaux with equal number of sprays for each, a great saving in copper sulfate could be made. Experiments to determine whether or not a less concentrated form of Bordeaux mixture than the 5-5-50 formula could be successfully used were started after it was shown that successful field control could be obtained with this mixture.

In 1936, the following tests with different concentrations were made:

Bordeaux 2-2-50	-	bi-weekly sprays
Bordeaux 3-3-50	-	bi-weekly sprays
Bordeaux 5-5-50	-	monthly sprays

It was concluded from these tests that the monthly spraying with a 5-5-50 formula produced better control than a bi-weekly spraying of a 2-2-50 or a 3-3-50 formula.

In 1936, the Tela Railroad Company Research Department established a permanent research spray test on the Guaruma farms. In the Guaruma II experimental plots, Bordeaux 5-5-50 and Bordeaux 3-3-50 have been under comparative test since the first of 1939. A summary of these tests is given in Supplement No. 1 of this report. Each plot in this test consists of approximately 2.59 acres. Spraying is done from a stationary Bean pump reduced down to a capacity of 15 gallons per minute and powered by a 13 H.P. electric motor.

These plots were examined by the writer on Nov. 20, 1942. The 5-5-50 Bordeaux plot had been on a 21 day cycle since January 1939. Approximately 17 sprays per year are applied with this cycle. While practically complete control was produced, some disease was present (Fig. VII). Apparently, even with this number of sprays per year, some disease may show when a 21 day cycle is practiced. It was concluded that if spray cycles had been shortened during the rainy season and lengthened during the dry season, better results would have been obtained.

The 3-3-50 plot had been on a 21 day cycle from January 1941 until November 1941. In November 1941, a change was made to a 14 day cycle. The change was made because no satisfactory control was obtained. On Nov. 20, 1942, the bananas in this plot showed scattered disease with severe disease in spots. It was evident that practical control was not obtained.

These tests confirmed those run in 1936 showing that a 5-5-50 spray on a 21 day cycle controlled disease while a 3-3-50 spray on a 14 day cycle produced only partial control. In amount of copper applied per acre, a 5-5-50 mix on a 21 day cycle is equivalent to a 3-3-50 mix on a 12.6 day cycle.

In addition to the Experiment Station tests, the various Bordeaux concentrations were given thorough field tests. The following field tests summarized in Table IV indicated, because of the shift in acreages sprayed with the various concentrations, that the 5-5-50 formula was the only one which gave practical field control.

TABLE IV - PERCENTAGE OF ACREAGE SPRAYED WITH VARIOUS CONCENTRATIONS

OF BORDEAUX MIXTURE - TELA RAILROAD COMPANY

1939 - 1942

Concentration	1939	1940	1941	Tela Farms 1942	Cortes Farms 1942
3-3-50	27.3%	8.6%	-	-	-
4-4-50	17.9	23.0	17.9%	1.4%	2.8%
5-5-50	54.8	68.4	82.1	98.1	95.5
Cuprocide				.5	1.7

Data presented in Table IV gives the percentages of acreages sprayed from 1939 through 1942 with various concentrations of Bordeaux mixture on the Tela Railroad Company holdings ranging around some 40,000 acres. These data show that tests with a 3-3-50 and a 4-4-50 concentrations were thoroughly run in 1939 and 1940 and that these concentrations had practically been discontinued in 1941 and 1942. They were stopped because of failure to produce practical control. It was found necessary to use the 5-5-50 formula for efficient field control.

Since the spray concentration and the spray cycles are so closely associated in efficient control, a further amplification of the most efficient concentration will be found under the heading of "Analyses of Farm Experiments on Concentrations and Spray Cycles" discussed in the following pages.

Analyses of Farm Experiments on Concentrations and Spray Cycles

Excellent field data relative to the use of different concentrations of Bordeaux mixture as well as on the utilization of different cycles in an attempt to reduce cost is presented in Chart 1. These data amplify and corroborate the conclusion arrived at in the discussion of concentrations and number of sprays required per year. The farm experiments were run over a period of years from 1938 through 1942 on an average of some 15,500 acres of sprayed bananas on Tela farms. These data are presented to give a clearer picture of representative field tests run to determine the most efficient concentration and number of sprays per year. Practically identical results were obtained on the Cortes farms consisting of some 16,700 to 24,169 acres during these years. The Cortes farms are located across the river from the Tela farms and are under the supervision of a separate superintendent. A summary of the data is presented in Supplement IV.

Data presented in Chart 1 gives a complete picture of farm tests run to determine the most efficient sprays and number of times to spray during a year in the Tela farms area. Bordeaux strengths used are represented in various colors: red, 5-5-50; brown, 4-4-50; green, 3-3-50; blue, copper lime dust; and yellow, not sprayed. The dust and non-sprayed areas were small and only present in 1938, so may be ignored in this discussion. The typewritten figures show the cycles of sprays in days and the area covered by each concentration

in percent. At the base of the chart for each year is given a summary of the cost of spraying per acre, the number of times sprayed or covered, the average spray cycle, the tons of copper sulfate used and the average acreage sprayed. In these tests, attempts were made to reduce the cost of spraying operations on a large scale by the use of lower concentrations of Bordeaux mixture and by the lengthening of time between sprays, thereby reducing the number of sprays per year.

In 1938, during the first 7 months, a 5-5-50 Bordeaux was used on a 14 to a 15 day cycle on a majority of the acreage. Some 3-3-50 Bordeaux was used. Since control was accomplished during these months, it was decided to use for the last five months more of the 3-3-50 and reduce the number of sprays by increasing the cycle from 14 to 17 and 19 days. At the end of the year, control was still good, but cost figures were high, amounting to $49.97 for 23.8 sprays during the year and the use of 4024 tons of copper sulfate.

Because of this excellent control it was thought that spraying costs could be reduced by a reduction of the spray concentration and the number of sprays during the year. Therefore, it was decided for 1939 to use a 3-3-50 Bordeaux over the majority of the acreage, a 4-4-50 over less and little of a 5-5-50 formula. At the same time spray cycles were lengthened to from 23.2 to 25.6 days. By November, with this reduced schedule, it was noted that disease was gaining headway so that all but 19% of the acreage was placed on a 5-5-50 formula with 2 sprays a month. In December, the entire acreage had to be placed on a 5-5-50 formula with a cycle of 15.5 days to control the disease. The costs for that year were lowered to $34.50 and the tonnage of copper sulfate to 2975. The lowered cost and use of copper was due primarily to the use of the 3-3-50 Bordeaux. This, however, was done at the expense of increased disease that needed added attention next year.

In January of 1940, somewhat over half the acreage was placed on a 3-3-50 formula and 22.5 day cycle, but disease development forced the management to resort to a 5-5-50 formula in February on a 19.6 cycle. Spraying was continued throughout the year with a 5-5-50 formula and a 19.4 to 31.4 day cycle, except for a small acreage during April and May. This greater strength formula was found necessary to hold the disease in check. Because of the use of the 5-5-50 formula and the reduction in time between sprays, necessitating more sprays during the year, the costs and amounts of copper used that year went up again to $37.54 with a consumption of 3333 tons of copper sulfate. Disease control at the end of the year was good, so it was proposed to reduce the number of sprays drastically during the next year in order to reduce costs.

In 1941, a 5-5-50 formula was used throughout. A spray cycle of from 36 to 37 days was practiced for January and February but as disease appeared the time between sprays had to be gradually lowered to effect control to a cycle of 21.2 days in December. The increased number of sprays during the latter part of the year was necessary to hold the disease in check. In spite of this, disease was prevalent during the last month of the year. Costs, however, were reduced to $34.25 and the tonnage of copper sulfate down to 2994.

This reduction in cost because of less spraying during 1941 resulted in more disease, thereby necessitating more frequent sprays during 1942, which brought the costs up to an estimated $44.36 per acre, with a consumption of 3643 (estimated) tons of copper sulfate.

The number of sprays applied in 1942 were 15.8 as compared with 13.5 in 1941. It was found, however, that the attempt to reduce costs by fewer sprays in 1941 resulted in partial loss of control. This partial loss of control made it necessary to apply more sprays in 1942 in order to effect complete farm control. In other words, a saving in one year apparently must be made up the next, if disease control is to be attained.

These field data as presented in Chart 1, give a good picture of the required Bordeaux spray concentrations and the number of sprays necessary each year to produce practical farm control. Since these field data were obtained from an acreage of mature bananas only, the figures for the average number of sprays used per year do not correspond to those given for the Tela farms under the discussion of "Least Efficient Number of Sprays." The figures used in the later discussion were for all farm operations, including young and mature plantings and plantings of independent growers. The 3-3-50 formula did not keep the disease in check when applied according to the schedule used. The 4-4-50 formula also failed to give sufficient control with the cycles employed. The 5-5-50 formula did satisfactorily control the disease when an average of 15.8 to 16.4 sprays were applied during the year. Apparently the 5-5-50 Bordeaux did not produce sufficient farm control when only an average of 13.5 sprays per year were applied.

Experiments to Determine the Least Efficient Number of Sprays Required Per Year

Spray cycles represent the number of days between sprays and consequently determine the number of sprays applied during the year. It is obvious that, for lower spray costs and lower consumption of copper sulfate, it is essential that the number of sprays applied during the year be kept down to a minimum. The length of spray cycles is based on the life history of the fungus, the plant growth, the pumping capacity of the spray plant, the efficiency of the labor and the number of days favorable to spraying.

During dry weather, the fungus is lss active and the spray cycles may be lengthened. In wet weather they must be shortened because of the greater activity of the fungus. The banana plant throughout the stage of vegetative growth puts out a new leaf on the average of about once every seven days. The average leaf continues to function for about twelve weeks. In an infected area, there are always spores to cause new infection, and it is most important that the new leaves are given a protective covering of the fungicide as early as possible after they unfold. While it is practically impossible to spray all new leaves soon enough to prevent some slight infection, it is possible to spray on a short enough cycle to keep secondary infection at a minimum. It is believed that where disease causes serious damage to the leaves, it is the result of secondary infection from spores produced on older spots on the same or nearby leaf surfaces. This is the most likely explanation of the fact that spraying cycles of longer than four weeks have not been found to maintain control.

The frequency at which a project can be covered is limited also by the pumping capacity and the number of hours favorable for spraying that are available during the week or month. In the rainy season, one can plan on not more than five good days out of seven. The standard pumping plant can supply spray mixture for fourteen spray gangs, and these fourteen gangs will average about 65 acres a day under present conditions. This means that a 900 acre project can be covered in about 14 days of continuous spraying. The choice of spraying interval is thus restricted to from between two and four weeks.

The following data on field tests and experiments are presented to show what studies have been made to determine the least efficient number of sprays required during the year.

Prior to 1939, excellent field control of disease had been obtained with a 14 day cycle, but with costs and copper sulfate consumption too high. A gradual reduction in cycles, therefore, was carried out on the Tela Railroad Company farms from 1939 through 1942. The data presented in Table V gives a summary of the percentage of acres under various spray cycles during this period. These data show that the number of cycles of sprays which gave good control fell between 14 and 28 days. A gradual reduction of acreage on a 14 day cycle was accomplished along with practical field control. For example, in 1939, some 20.9% of the acreage was sprayed on a 14 day cycle while in 1941, only 13% of this acreage was on this cycle, and in 1942 only 10.4% on the Tela farms and 18% on the Cortes farms. The spray cycle therefore was gradually increased for the majority of the acreage, thereby reducing the number of sprays necessitated during the year for farm control.

TABLE V - PERCENTAGE OF ACREAGE UNDER VARIOUS SPRAY CYCLES

TELA RAILROAD COMPANY

1939 through 1942

Cycle	1939	1940	1941	Tela Farms 1942	Cortes Farms 1942
6 day	-	-	-	.1%	-
10 day	-	-	.4%	-	-
14 day	20.9%	20.1%	13.0	10.4	18.0%
21 day	12.6	26.5	15.0	24.6	40.0
28 day	62.1	48.9	52.0	63.0	42.0
35 day	-	-	2.8	1.9	-
42 day	4.4	3.6	16.0	-	-
56 day	-	-	.4	-	-
84 day	-	-	.1	-	-
Fixed	-	.8	.3	-	-

During 1940, an experiment was conducted to determine whether spraying could be done on a fixed schedule and at a still further reduction in the number of sprays applied during the year. Since it had been determined that less severe infection occurs between Dec. 13 and May 1, it was thought that possibly no sprays were needed during that period. In order to prove this assumption, the following tentative spray schedule with lengthened cycles and reduced applications was followed in this test.

Tentative Spray Calendar with Bordeaux Mixture

May 1	-	June 1	5-5-50	21 day cycle	2 applications
June 12	-	August 7	3-3-50	28 day cycle	2 applications
August 8	-	December 12	5-5-50	21 day cycle	6 applications
December 13	-	May 1	No spray		
				Total	10 applications

The experiment was started on January 1, 1940 on four different farms with varying climatic conditions. On one farm, the normal spraying was resumed in April because of severe disease development. Severe infection was noted in August on another farm. On all farms in which this schedule was practiced throughout the year, severe infection resulted and considerable fruit was lost. It was concluded that because of varying weather and plant growth under a variety of conditions, it would be impossible to abide by a fixed spray schedule as planned for this test. It was determined also that spraying must be continued during every month of the year for complete control and that 10 applications are not sufficient. Apparently the accepted spray schedule consisting of spraying throughout the year with lengthening of cycles from February 1st to May 15th and a gradual shortening of cycles depending on weather conditions from May 15 until November 1st will have to be practiced for effective control.

The calculation of spray cycles and the number of sprays necessary during the year on any large plantation is a complicated matter. Spray cycles may be shortened or lengthened depending upon local climatic conditions and the virulence of infection. Because of these factors, the cycles may vary on different farms planted over a large acreage. No definite schedule can be applied to each farm of 1000 acres or even a smaller acreage on a large plantation. In actual farm spraying operations, the treatment for any particular area may be changed as to strength of mixture or interval between applications whenever it seems advisable. The treatment decided upon for any particular area is dependent upon the amount of disease present at the time and upon the known history of that area. Continued close observation of all areas has been maintained by men especially selected and trained for this purpose. Familiarity with local conditions and tests conducted over a period of years, therefore, determines just what the best cycles are for all areas concerned. From such data, obtained by the spray masters who are in direct charge of each project, is computed the estimated required number of cycles and number of sprays necessary for any particular year. Such data is presented in Supplement No. 3 for the Tela farms and Supplement No. 4 for the Cortes farms.

The best data available for a determination of the least efficient number of sprays required per year are the farm records of the Tela and Cortes division of the Tela Railroad Company covering a period of years from 1938 through 1942. These records as presented in Table VI include the average project acres sprayed and the average number of sprays applied each year.

TABLE VI - AVERAGE NUMBER OF SPRAYS PER YEAR - ALL PROJECTS

TELA RAILROAD COMPANY

Year	Average Project Acres	Average No. Sprays Per Year
	Tela Farms	
1938	15,508	23.8
1939	15,387	17.5
1940	14,733	16.7
1941	14,508	15.5
1942	16,318	17.2
	Cortes Farms	
1938	16,786	19.1
1939	22,143	14.8
1940	22,815	15.9
1941	24,169	15.3
1942	24,138	17.2

According to these data, the Tela farms actually used a minimum of 15.5 sprays per year in 1941 and a maximum of 23.8 in 1938, and the Cortes farms employed a minimum of 14.8 sprays per year in 1939 and a maximum of 19.1 sprays in 1938. Since 1938 was the first year in which disease was actually gotten under control over the entire acreage, it must be assumed that more sprays per year were required than during the succeeding years. In 1940 good farm control was obtained with 16.7 sprays per year in the Tela farms and 15.9 sprays in the Cortes farms. In 1941 attempts were made to lower costs by decreasing the number of sprays. Too few sprays were applied with a result of insufficient control which made it necessary to apply more spray in 1942 to effect control. Consequently the number of sprays applied during 1941 undoubtedly were too few for efficient control and the number applied in 1942 in order to bring back control were too many for an average year. In other words, if too little spray is applied in one year, disease creeps up with a resultant necessity for more sprays the following year if complete control is to be obtained.

The Tela farms are on one side of the Ulua River and the Cortes farms are on the opposite side. Each group of farms, Tela and Cortes, has its own Superintendent who directs all operations independently. Obviously, because of this and differing climatic conditions, the number of sprays applied during

the same year in each area would vary from that applied in the other. In 1941 complete control was not produced when 15.5 sprays were applied in the Tela farms and 15.3 sprays in the Cortes farms. Because of this fact, 17.2 sprays were applied in 1942 to produce complete control. These data show that practical farm control over extensive acreages with a 5-5-50 Bordeaux mixture can be obtained over a period of years when between 15.3 and 17 sprays are applied. The most efficient number of sprays applied per year, as will be shown later, is linked with the gallonage of spray applied per acre.

Experiments to Determine the Least Efficient Gallonage of Bordeaux Per Acre Per Year

The amount of spray material used to cover an acre of mature bananas is an important factor in disease control and in cost of control. For efficient control, the entire leaf surface of a planting of bananas should be covered. The amount necessary, therefore, is really dependent upon the actual leaf surface present. The latter is dependent upon the number of plants per acre and the size of these plants.

Each banana plant produces only one stem of fruit and in order to get the maximum possible production, it is necessary to grow as many plants per acre of land as can be done without crowding. The number of plants that can be grown per acre depends upon the size attained by the individual plants. This will vary for different areas because of differences in growth factors. The number and distribution of the plant population is controlled by frequent cutting down of surplus plants or transplanting them to open spaces. Where the plants grow to near the maximum size, there is room for only approximately 540 to the acre. When the plants are comparatively small at maturity as many as 700 may be left per acre.

The most effective coverage results when just enough spray is applied to the leaves to avoid drip. A certain amount of wastage is unavoidable. Some of the spray misses the plants entirely and some drips off onto the ground. The efficiency of the workmen doing the spraying and the condition of the equipment are important factors. Unavailability of essential materials and items of equipment due to war conditions are gradually lowering the efficiency of the spraying. Leaks and breaks are more common. Actually on the farms varying amounts of spray material are used depending upon local conditions. Experience from spraying thousands of acres of bananas indicates that the quantity of liquid spray material required for proper coverage of an acre of mature plants is from about 250 to 280 gallons.

The only figures available on the average gallons of Bordeaux mixture used per acre per year are those kept by the Farms Department of the Tela Railroad Company covering the period from 1938 through 1942. These data, presented in Table VII, represent the gallonage used under actual total operations of all acreage in bananas during these years. Since newly planted bananas are included, the average gallonage used would undoubtedly be lower than that needed to spray only mature bananas. For 1943 only mature bananas will be sprayed for no new plantings have been made.

TABLE VII - AVERAGE GALLONS OF BORDEAUX APPLIED PER ACRE PER SPRAY

ACTUAL TOTAL OPERATIONS

TELA RAILROAD COMPANY

	1938	1939	1940	1941	1942
Tela Farms	264	262	267	261	261
Cortes Farms	262	260	263	265	259

According to the data presented in Table VII, the gallonage of Bordeaux applied per acre per spray for all banana plantings was from a minimum of 259 gallons to a maximum of 267. The average gallonage used per acre from 1938 through 1942 for Tela farms was 263 and that for the Cortes farms was 262. It appears, therefore that, between 260 and 267 gallons per acre of spray material should be sufficient for control. These figures represent averages of the actual amounts used during all spray operations, including young bananas, mature bananas and in blown down areas.

When mature bananas only are sprayed, it would take somewhat more spray per acre to cover these plants than it would to cover a planting of young and old plants.

Table VIII presents a summary of average gallons of Bordeaux used to spray mature banana plants in the Tela and Cortes farms.

TABLE VIII - AVERAGE GALLONS OF BORDEAUX APPLIED PER ACRE PER SPRAY

MATURE BANANAS

TELA RAILROAD COMPANY

	1938	1939	1940	1941	1942
Tela Farms	264	263	269	268	265
Cortes Farms	267	266	273	273	268

According to the data presented in Table VIII, the average gallonage of Bordeaux applied per acre per spray for mature bananas was from a minimum of 263 gallons to a maximum of 273 gallons. If we assume that an average of these amounts over a period of years will give a figure that represents at least an approximate amount for efficient spraying, this would be 266 gallons for the Tela farms and 270 gallons for the Cortes farms. It appears, therefore, that between 263 and 273 gallons per acre of spray material is an efficient amount for control for mature bananas.

With 540 sprayable plants to an acre, using 265 gallons per acre, each plant would receive approximately 2 quarts of spray, and with 700 plants to the acre, each plant would receive approximately 1-1/2 quarts of spray. This

would appear to be a minimum amount to adequately cover the leaf surface of the larger plants with less plants per acre and the smaller plants with more plants per acre.

The data presented above shows that it takes on an average of from 260 to 267 gallons to spray an acre of bananas in a plantation under normal operations with newly planted and mature banana acreage. For spraying mature bananas alone, the data shows that it would take on an average from 263 to 273 gallons per acre.

Computation of the Amount of Copper Sulfate Necessary per Acre

The experimental and field data presented in the foregoing pages indicate the following:

1. That a 5-5-50 formula of Bordeaux is most efficient for farm control.

2. That the least efficient average number of sprays per year lies between 15.3 and 17.0. For use as a measuring stick in the evaluation of spray programs, it is believed that an average number of sprays per year of between 15.4 and 15.8 may justly serve the purpose. This number of average sprays will apply only to those plantings in which practical field control has been attained over a period of years.

3. That the most efficient average gallons of spray to apply per acre varies between 260 and 270 gallons for the average plantation practice with newly planted and mature bananas and between 265 and 275 gallons for a plantation of mature bananas. Since no new plantings have been made during 1942, only mature bananas will be sprayed in 1943.

Since a 5-5-50 formula of Bordeaux mixture contains 5 pounds of copper sulfate in 50 gallons of water, 100 gallons of the spray contains 10 pounds of copper sulfate. Assuming that it takes on an average of 265 gallons to spray one acre of a plantation with young and old bananas, it would take 26.5 pounds of copper sulfate per acre per spray. At the rate of 268 gallons per acre for mature bananas, it would take 26.8 pounds of copper sulfate per acre per spray. If we assume that the average number of sprays to apply per year falls between 15.4 and 15.8 and using 265 gallons per acre per spray for a plantation with young and old bananas and 268 gallons per acre per spray for a plantation of mature bananas, we would use the following amounts of copper sulfate per acre per year.

Plantations with newly planted and mature bananas.

15.4 sprays per year at 265 gallons per spray requires 408.1 pounds of copper sulfate per acre per year.

15.6 sprays per year at 265 gallons per spray requires 413.4 pounds of copper sulfate per acre per year.

15.8 sprays per year at 265 gallons per spray requires 418.7 pounds of copper sulfate per acre per year.

Plantations of mature bananas

15.4 sprays per year at 268 gallons per spray requires 412.7 pounds of copper sulfate per acre per year.

15.6 sprays per year at 268 gallons per spray requires 418.1 pounds of copper sulfate per acre per year.

15.8 sprays per year at 268 gallons per spray requires 423.4 pounds of copper sulfate per acre per year.

DISCUSSION

The above average figures on the amount of copper sulfate required for control are based on the experimental and field tests run by the Tela Railroad Company in their banana plantations on the North Coast of Honduras. In these areas, a variety of climatic conditions are encountered varying from drier areas with a rainfall of 40 to 45 inches per year to wetter areas with 80 and over inches per year. Since a variety of conditions are encountered in the banana growing areas of Central America, it cannot be expected that these average figures will apply directly. It is believed, however, that they will serve as a yardstick for the evaluation of copper sulfate needs in the various banana areas.

These data appear to give a true range of amounts of copper sulfate necessary for practical farm control of Sigatoka disease as it occurs under the average conditions that exist on the North Coast of Honduras. In the determination of the amount of copper sulfate required per acre per year for any locality, it must be remembered that 5 to 10 pounds of copper sulfate per acre more or less is not much under practical spraying operations on a large plantation of some 40,000 acres. This is true because only 10 pounds of copper sulfate is present in 100 gallons of the spray mixture. If the spray is not applied in the most efficient manner or the equipment is faulty, due to inability to secure spare parts, it is an easy matter to waste 10 pounds of copper sulfate per acre. Because of these facts, a practical amount of copper sulfate must be figured on, to provide sufficient for practical farm control. In calculating total amounts of copper sulfate required for a plantation of some 40,000 acres, a saving of 5 to 10 pounds amounts to a large figure. In attempts to make such savings, however, it must be remembered that it is not a simple matter under practical farm operations to stay within limits of a difference of 5 to 10 pounds of copper sulfate per acre when used in spraying operations.

With the above figures as a basis, the following Table IX has been prepared to show just how much copper sulfate is used per acre per year, when from 15 to 17 sprays are applied a year at 260, 265, and 270 gallons per spray. These tables should provide a ready yardstick in evaluating the efficiency of spraying operations conducted under conditions similar to those in the banana growing regions of the North Coast of Honduras when we assume that somewhere between 400 and 425 pounds of copper sulfate is the most efficient amount for control.

TABLE IX - POUNDS OF COPPER SULFATE USED PER ACRE PER YEAR WITH VARYING NUMBER OF SPRAYS PER YEAR AND GALLONAGE PER ACRE PER YEAR

Average No. Sprays per Year	Average Gallons per Acre per Spray	Pounds Copper Sulfate per Acre per Year
15.0	260	390
15.2	"	395.2
15.4	"	400.4)*
15.6	"	405.6)
15.8	"	410.8)
16.0	"	416.0)
16.2	"	421.2)
16.4	"	426.4
16.6	"	431.6
16.8	"	436.8
17.0	"	442.0
15.0	265	397.5
15.2	"	402.8)*
15.4	"	408.1)
15.6	"	413.4)
15.8	"	418.7)
16.0	"	424.0)
16.2	"	429.3
16.4	"	434.6
16.6	"	439.9
16.8	"	445.2
17.0	"	450.5
15.0	270	405)*
15.2	"	410.4)
15.4	"	415.8)
15.6	"	421.2)
15.8	"	426.6)
16.0	"	432.0
16.2	"	437.4
16.4	"	442.8
16.6	"	448.2
16.8	"	453.6
17.0	"	459.0

* Assumed average range of amount for practical control.

CONCLUSIONS

The investigations have shown that Sigatoka disease is a serious threat to banana operations. Control must be exercised if banana operations are to be continued.

Experiments on control have shown that the use of sanitation methods, fertilizers, or resistant varieties will not control the disease.

Attempts to grow bananas without fungicidal control in recent years failed.

Carefully conducted investigations with all dusts and sprays on the market have shown the following:

Of all dusts tested, copper lime dust was the only one of the copper and sulfur dusts tested that effected control. Its use was discontinued because of the expense. The amount of copper sulfate applied per acre was somewhat more than needed for control with the proper 5-5-50 Bordeaux spray program.

Of all copper sprays tested, Bordeaux mixture 5-5-50 formula was determined to be the most efficient for farm control.

In the sulfur group of sprays, it was found that none produced satisfactory control throughout the year. All sulfur sprays leave a residue on the fruit that cannot be removed by any known efficient method.

No substitute sprays to take the place of copper sprays were found to be effective. One organic spray known as "Fermate" is still under test and it is hoped that it will show effective control.

Tests with the important stickers and spreaders on the market in attempts to increase the efficiency of lower concentrations of Bordeaux mixture and to lengthen the spray cycle failed to produce efficient results.

Permanent spray installations throughout all plantations were found to be the most efficient.

The large investment in spray equipment and the high cost of spraying and washing makes it imperative for any company to reduce costs as low as possible.

It was found that all copper spray residues could be easily removed by dipping the fruit in a weak hydrochloric acid solution. All fruit must be dipped and washed before shipment. Sulfur spray or dust residues could not be removed efficiently thereby eliminating these fungicides for practical control.

Extensive experiments and field trials covering a period of years from 1936 through 1942 with Bordeaux sprays have shown the following facts:

1. That Bordeaux mixture 5-5-50 formula is the most efficient for farm control.

2. That the least efficient average number of sprays to apply per year lies between 15.3 and 17.0. An average of between 15.4 and 15.8 has been assumed to be a fair number to use in the evaluation of spray programs practiced under similar conditions.

3. That the most efficient average gallons of spray to apply per acre varies between 260 to 270 gallons.

The following amounts of copper sulfate necessary per acre for practical farm control have been arrived at from the studies conducted:

Between 408 and 419 pounds of copper sulfate per acre per year for plantations with newly planted and mature bananas.

Between 412 and 423 pounds of copper sulfate per acre per year for plantations with mature bananas.

On the basis of these figures, a table has been prepared indicating amounts of copper sulfate required per acre per year when varying numbers of sprays per year and varying gallonage of spray per acre are used. It is assumed that this table will provide a ready yardstick in evaluating the efficiency of spraying operations conducted under conditions similar to those practiced in Honduras.

The tests with the organic fungicide Fermate should be continued for final conclusion. This fungicide is the only promising substitute for a copper spray known that has not already been thoroughly tested.